July 11, 2016

Office of the Secretary,
Federal Communications Commission,
445 12th St., SW, Room TW-A325,
Washington, DC 20554

Re: OET Advisory Council (TAC) Noise Floor Technical Inquiry
ET Docket No. 16-191

via ECFS

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I am an Electrical Engineer now retired after a 40 year career in electronic product development. I became licensed as a 1st Class Radiotelephone Operator in 1968 and as Extra Class Amateur Operator AD9DP in 2008. My interest in this inquiry is as an Amateur Radio operator and member of the public.

1. **Is there a noise problem?**
   Yes, at least for legacy analog services. New digital services can minimize it with data redundancy and error correction at the expense of information bandwidth and spectrum spreading at the expense of occupied bandwidth. Packet data can support reuse of the greater occupied bandwidth at the expense of latency. Bandwidth can also be traded for noise immunity by angle modulation, e.g. wideband FM, but frequency reuse is limited to the so-called capture effect. Little can be done to improve the noise immunity of linear modulations such as AM, SSB, or VSB other than companding.

   a. **If so, what are the expected major sources of noise that are of concern?**
      Switching power supplies of all types and topologies, including but not limited to CFL, LED, and fluorescent lamp ballasts, DC adapters, AC inverters, computers and set top boxes, displays and HDMI cables, and aging power distribution systems.

      The noise floors are rising from the bottom bands up due to the ubiquity and continuing adoption of incidental and unintentional radiators of all types. The noise floors are also extending to higher bands due to the performance, energy efficiency, size, weight and cost advantages derived from higher clock speeds, switching speeds (internal *di/dt,*) and switching rates. These will continue to increase as semiconductor devices improve.

   b. **What services are being most impacted by a rising spectrum noise floor?**
      Legacy services using linear modulation. The Amateur Radio Service is one such example. Though most Amateur operators can track a local interferer to its source or know another amateur who can, we have no remedy for the rising noise floors in our MF and HF bands. To the good, that noise has maintained our legacy interest in CW ("Morse code") and led to experimentation with highly robust narrow-band digital modes such as PSK31 and JT65.

c. **If incidental radiators are a concern, what sorts of government, industry, and civil society efforts might be appropriate to ameliorate the noise they produce?**
Having been responsible for the Part 15 compliance of many electronic products, I believe the present Part 15 and Part 18 Rules and emissions limits represent an acceptable trade-off between emissions and product size, weight, and cost.

There have been calls from the Amateur Radio community and broadcasters for tighter emissions limits on Part 15 and Part 18 devices, but I believe little further reduction in emissions from compliant devices will be achieved without unacceptable increases in their size, weight, and cost, or fundamental advances in the materials science behind the magnetic and dielectric materials used in filter components.

Although there will always be non-compliant products and defective units among compliant ones, I believe most name branded consumer electronics that carry FCC IDs are compliant, but no more so than necessary because they compete in markets that are size, weight, cost and performance-sensitive. The burden for new communications services must shift to defensive design of the communications systems themselves. This requires knowledge of the noise floors in all bands.

For the protection of legacy services, more aggressive enforcement of existing emissions regulations is the best option. I have seen too many electronic products that carried no FCC ID on either product or packaging. Enforcement should be tightened to the point that any product found at retail without a valid FCC ID is subject to recall. To this end, recently threatened reductions in FCC enforcement personnel would not be helpful.
I believe the threat of FCC enforcement coupled with an occasional enforcement action will keep most name brand manufacturers emissions-compliant because the financial consequences of a recall are too great. The size of the US market for consumer electronic products makes FCC enforcement globally effective.

2. **Where does the problem exist?**
   a. **Spectrally**
      i. **What frequency bands are of the most interest?**
      A 2006 study for the World Meteorological Organization[1] (the "WMO Study",) suggests that the noise floor rises with decreasing frequency, having then been close to the room temperature KTB in the SHF band, rising to 30dB above it at VHF. Extrapolation suggests that the HF, MF, and LF bands are progressively noisier. All bands are of potential interest if future Rulemakings or frequency reallocations are to be informed. The AM broadcast band, for example, is already degraded, but that doesn't mean that MF frequencies are useless to some other transmission system.

   b. Spatially
      i. **Indoors vs outdoors?**
      Ordinary buildings offer insufficient shielding to reduce emissions from systems inside them. Any shielding of emissions from outside is either the same to the noise floor and the desired signal or only to the benefit of users within.

1 "Results of Ambient RF Environment and Noise Floor Measurements Taken in the U.S. in 2004 and 2005" https://www.wmo.int/pages/prog/www/TEM/SG-RFC06/Ambient-RF-noise.pdf

ii. **Cities vs rural settings?**
The WMO Study found differences between Urban, Suburban, and Rural areas at VHF and UHF frequencies. I believe most Amateur Radio operators would agree that HF amateur radio operations are more challenging in urban areas than in remote ("field day") locations. Amateur Radio is probably the service most sensitive to the effect of noise floors on distant, weak, analog signals - the "canary in the coal mine," so to speak.

iii. **How close in proximity to incidental radiators or other noise sources**?
It varies. Interference from motors or light dimmers is typically isolated to a home; interference originating in power distribution systems can radiate from the lines over a considerable distance; in any case, the cumulative sum of emissions from an immense number of incidental and unintentional radiators is potentially global at MF and HF frequencies where the earth and the ionosphere at times act to contain them.

iv. **How can natural propagation effects be accounted for in a noise study?**
It seems that for the purpose of designing noise-tolerant systems, the best metric would be the isotropic RMS noise power density at a given frequency, its overall statistical distribution, and any correlation(s) that can be found with population density, time-of-day, season, etc.

c. **Temporally**
Diurnal and seasonal effects govern usage in some classes of devices, e.g. lighting use increases at night, so the noise floor contribution from CFL and LED lamps should correlate to dark hours and electrical power demand. Ionospheric effects have both temporal and spectral variability which should be considered in the band planning for any study.
i. **Night versus day?**
ii. **Seasonally?**

3. **Is there quantitative evidence of the overall increase in the total integrated noise floor across various segments of the radio frequency spectrum?**
Perhaps. Commercial compliance labs *might* have files containing background noise data that was collected incidental to site attenuations for site certifications. Hopefully a broad notice of this inquiry will lead to the discovery of any such data.

a. **At what levels does the noise floor cause harmful interference to particular radio services?**
The Amateur Radio Service is already adversely affected across its MF and HF bands. The Broadcast services vary by frequency and modulation: Urban AM broadcast is degraded because urban noise levels may exceed the field strengths that can be attained from a single transmitter site to the edges of a metropolitan coverage area without skywave interference to stations in far away cities. Commercial FM broadcast has sacrificed much of the capture effect to reductions in modulation index for SCA, multiplex stereo, and now, HD Radio. This will be exacerbated by the proliferation of translators and the greater occupied bandwidth of HD Radio which itself exacerbates

multipath. High VHF and UHF terrestrial DTV so far seem less affected by the noise floors than by the vulnerability of the ATSC transmission system to multipath.

b. **What RF environment data from the past 20 years is available, showing the contribution of the major sources of noise?**
It might be possible to mine Part 15 or Part 18 filings, average them, and classify them by product type. Combined with historical shipment volumes, an aggregate model might show if the present urban noise floors were predictable.

c. **Please provide references to scholarly articles or other sources of spectrum noise measurements.**
The WMO Study previously footnoted sets a useful precedent. Its stated purpose was to profile the ambient noise floor within meteorological and space science bands used by NOAA. The available data is thus limited to those bands, all of them above above 136 MHz, with some potentially significant gaps between them. That study could be replicated and the original results used as a baseline to determine the increase in noise floors in those bands over the last twelve years or so. Its original database might inform the spectral, temporal, and spacial granularity needed in more comprehensive studies, at least for the VHF region and above. A similar study plan could be extended downward to LF, MF, and HF regions to place a "stake in the ground" for future trend measurements, modeling of the man-made sources, and future communications systems design.

4. **How should a noise study be performed?**
   a. **What should be the focus of the noise study?**
   To gather baseline data with a standardized method, preferably in isotropic RMS noise power density units and with adequate frequency, temporal, seasonal, and spacial resolution to potentially model and forecast the contributions of its various sources.

   b. **How should it be funded?**
   Public or crowd-funding would best avoid commercial agendas and biases.

   c. **What methods should be used?**
   Extrapolating the WMO Study's VHF results from 1 Hz to 9 Khz bandwidth and assuming the noise floor rises with further decreasing frequency suggests that LF through VHF data could be gathered using reference antennas and receivers sold for compliance measurements, e.g. per CISPR 16-1-1. The fastest result would be obtained by contracting with commercial compliance labs that already have such equipment. To improve spacial resolution, such systems could be built and deployed as mobile units in a manner similar to Google's StreetView.

   d. **How should noise be measured?**
      i. **What is the optimal instrumentation that should be used**?
      The best available, of course, but the less costly and the less proprietary, the greater the amount of data that can be gathered.

      ii. **What measurement parameters should be used for that instrumentation?**
      Standardized compliance measures are oriented to limiting the impact of an individual interferer on a nearby communications system, whereas the noise floor, if truly a floor, should appear as Gaussian noise. The calibration,

validation, and measurement parameters will depend on the equipment used and the detectors available, but in all cases the target should be an RMS noise power density in a test bandwidth free of coherent signals. Software defined radios (SDRs) are capable of such measurements with readily available computers, and standardized software could standardize the parameters. Since some SDRs lack preselection or have limited capability, the experimental plan must keep them well clear of intentional radiators and their inter-modulation products.

iii. **At what spatial and temporal scales should noise be measured?**
See other responses.

iv. **Should the monitoring instrumentation be capable of determining the directions of the noise sources? If so, how would those data be used**?
I don't see how directional data would be actionable. Dipole measurements in vertical and two orthogonal, horizontal planes that can be reported with or converted to an isotropic noise power density should be sufficient.

v. **Is there an optimal height above ground for measurements?**
At or very near ground seems to me to offer the best measure for applicability to terrestrial systems and gathering the maximal number of data points at lowest cost.

e. **What measurement accuracy is needed?**

i. **What are the statistical requirements for sufficient data? Would these requirements vary based on spectral, spatial and temporal factors?**
The statistics of the original WMO Study database might be informing on this.

ii. **Can measurements from uncalibrated, or minimally calibrated, devices be combined?**
Combining would be undesirable, but *collecting* data under multiple classes of calibration could be helpful. In the crowd-sourced proposal below for example, measurements could be solicited in a class designated for pre-accepted commercial receivers and antennas, another class for pre-accepted receivers and "homebrew" antennas, and a further class with arbitrary equipment, but a pre-accepted calibration method. Other classes come to mind. Subsequent post processing or modeling could then choose which subset(s) to include for a desired trade off between the number of data points available and the presumed accuracy of each.

iii. **Is it possible to "crowd source" a noise study?**
I believe so. The Amateur Radio community would be particularly motivated to take, log and electronically submit noise measurements if it could use one of several easily reproducible antenna designs and pre-approved software-defined radios and software. Preferably, the latter would be an FCC-sponsored, open-source SDR-based noise-measurement application (include Linux builds, please.) That application could optimize and standardize the detection method, reduce operator error, ensure consistency and support electronic submission to eliminate transcription error. Calibration sources could be built by FCC contractors and loaned to amateur radio organizations for use in noise calibration events at

"hamfests." Properly designed, such a program might produce a large number of consistent data points at minimum public expense and could be conducted internationally as well as domestically. It could then become a low cost ongoing program for trend tracking.

f. **Would receiver noise measurements commonly logged by certain users (e.g. radio astronomers, cellular, and broadcast auxiliary licensees) be available and useful for noise floor studies?**
Potentially yes, in VHF bands and above where such services are typically allocated.

g. **How much data must be collected to reach a conclusion**?
Enough that correlation between the noise floor and the likely sources can be established for forecasting. The overall trend would be interesting, but not as actionable.

h. **How can noise be distinguished from signals?**
One man's noise is another man's signal in this spread spectrum age, so a test method is needed that excludes intentional radiators at each test location and measurement bandwidth. One approach might be an online tool that would scan the FCC's ULS database for a targeted band and select test frequencies within its white spaces. This could be made a part of the SDR application for a crowd-sourced study. Better yet, the SDR application could be designed to detect and either avoid or reject any coherent signal(s) in the bandwidth of a measurement.

i. **Can noise be characterized and its source identified?**
Given a sufficient number geolocated noise floor measurements over a range of urban, suburban, rural, and desolate locations, day, night and during transition; in-band white-space, and near-band, then multiple regression techniques might be able to tease out the relative contributions of galactic, skywave, ground wave, line-of-sight, IBOC, and Part 15 and Part 18 incidental radiators from which the future increase in noise floor by cause might be estimated. Additional correlations might be found with FCC ULS data, Part 15 and Part 18 filing data, local population densities and electrical power consumption.

Even if regression techniques were to find no usable correlation(s), the raw data set would be valuable as a baseline for future projections. Admittedly, this is no small task and not certain to identify discrete causes, but I think it essential to try in order to inform future Rulemakings and communications system designs.

ii. **Is there a threshold level, below which measurements should be ignore**d?
I suggest disregarding any measurement less than 3dB above the minimum detectable signal of the measurement system.

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